TITLE OF THE INVENTION

TORQUE DETECTOR

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of Korean Application No. 2003- 48596, filed July 16, 2003, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates, in general, to a steering system for a vehicle and, more particularly, to a torque detector for a vehicle steering system, which detects torque on a steering wheel.

Description of the Related Art

A power steering system provides an auxiliary steering force to wheels using an additional auxiliary driving device, so that a steering force, which should be applied to a steering wheel by a user while a vehicle drives at low speeds and stops, is reduced, thus facilitating a manipulation of the steering wheel. An Electronic Power Steering (EPS) system provides a relatively large auxiliary steering force while a vehicle drives at low speeds and stops, and provides a relatively small auxiliary force while the vehicle drives at high speeds, thus satisfying reduction of the steering force while the vehicle drives at low speeds and stops and driving stability while the vehicle drives at high speeds.

In the EPS system, a direction and magnitude of the auxiliary steering force are determined according to a rotation direction and rotation angle of the steering wheel. For this purpose, a torque sensor is used. A principle of torque detection of the torque sensor is to use variation of magnetic flux around a torque detection coil due to rotation of the steering wheel. A torsion bar is disposed between a wheel driving shaft and a steering wheel driving shaft, and the torsion bar is twisted by the rotation of the steering wheel. The twisting of the torsion bar varies the magnetic flux around the torque detection coil, so that a magnitude of an inductance of the torque detection coil varies with the variation of the magnetic flux, thus varying an amplitude of a voltage induced to the torque detection coil. An increase or a decrease in the amplitude of the induced voltage becomes an index that indicates the rotation direction and rotation angle of the steering wheel.

FIG. 1 is a block diagram of a conventional torque detector disclosed in Japanese Patent Publication Hei 8-68703. In the conventional torque detector of FIG. 1, an Alternating Current (AC) voltage output from a current amplifier 31 and an inverse AC voltage output from an inverse current amplifier 32 are applied to both ends of a coil circuit including a coil L_1 and a coil L_2, respectively. A difference between a torque detection voltage detected in a bridge circuit including the coil L_1, the coil L_2, a resistor R_1 and a resistor R_2, and a reference voltage is amplified, and then a torque detection signal T_S is obtained by synchronous detection and sampling.

FIG. 2 is a graph showing phase variation of an AC voltage signal V_B and a sampling pulse signal SPa in the conventional torque detector of FIG. 1. As shown in FIG. 2, only if phases of the AC voltage signal V_B and the sampling pulse signal SPa coincide with each other, accurate synchronous detection and sampling may be achieved. If the phases of the AC voltage signal V_B and the sampling pulse signal SPa

do not coincide with each other, sampling errors are generated as shown in FIG. 3. FIG. 3 is a graph showing variation of an output voltage of a sample-and-hold circuit 26 according to phase variation of the AC voltage signal V_B in the conventional torque detector of FIG. 1. As shown in FIG. 3, if the phase of the AC voltage signal V_B does not coincide with the phase of the sampling pulse signal SPa like V_B" shown in FIG. 2, an inaccurate peak value may be sampled like V_{SA}" shown in FIG. 3. If an accurate peak value is not sampled in a sampling time t_s, a torque detection signal T_S output from a voltage-to-current converter 39 is no longer valid.

SUMMARY OF THE INVENTION

Accordingly, it is an aspect of the present invention to provide a torque detector, which allows accurate torque detection even though a phase of a voltage applied to a coil circuit including a temperature compensation coil and a torque detection coil is destabilized by disturbance, such as temperature variation.

Additional aspects and advantages of the invention will be set forth in part in the description which follows and, in part, will be obvious from the description, or may be learned by practice of the invention.

The foregoing and other aspects of the present invention are achieved by providing a torque detector, including a synchronous detector to detect an AC voltage signal having a preset DC voltage level and a certain frequency, and generate a detection output signal, a bridge circuit in which a torque detection coil whose inductance varies with rotation of a steering wheel and a temperature compensation coil whose inductance varies with temperature variation are connected in series to each other, the detection output signal and the DC voltage being applied to both ends of the two

connected coils, respectively, the bridge circuit allowing a first detection voltage to be induced at a connecting point between the two coils by variation of the inductance of the two coils, and a signal converter to generate a torque detection signal having an amplitude corresponding to a difference between peak values of a preset reference voltage and the first detection voltage.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects and advantages of the invention will become apparent and more readily appreciated from the following description of the preferred embodiments, taken in conjunction with the accompanying drawings of which:

FIG. 1 is a block diagram of a conventional torque detector;

FIG. 2 is a graph showing phase variation of an AC voltage signal and a sampling pulse signal in the conventional torque detector of FIG. 1

FIG. 3 is a graph showing variation of an output voltage of a sampling hold circuit according to phase variation of the AC voltage signal in the conventional torque detector of FIG. 1;

FIG. 4 is a block diagram of a torque detector, according to the present invention;

FIG. 5 is a graph showing an AC voltage signal and a sampling pulse signal in the torque detector of FIG. 4, according to the present invention;

FIG. 6 is a graph showing a detection output signal and the sampling pulse signal in the torque detector of FIG. 4, according to the present invention;

FIG. 7 is a graph showing amplitude variation of a first detection voltage according to inductance variation of a temperature compensation coil and a torque detection coil in the torque detector of FIG. 4, according to the present invention;

FIG. 8 is a graph showing a second detection voltage obtained in a contact point between first and second resistors in the torque detector of FIG. 4, according to the present invention; and

FIG. 9 is a graph showing a first peak detection voltage output from a second detector according to phase variation of the first detection voltage in the torque detector of FIG. 4, according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Reference will now be made in detail to the present preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout.

A torque detector will be described with reference to FIGS. 4 to 9, according to a preferred embodiment of the present invention. FIG. 4 is a block diagram of a torque detector, according to the present invention. As shown in FIG. 4, an oscillator 402 is biased with a DC voltage V_{DC}, and generates an oscillation signal V_{OSC} having a certain frequency. A current amplifier 404 generates an AC voltage signal V_1 in which a current component of the oscillation signal V_{OSC} output from the oscillator 402 is amplified and a phase and an amplitude of a voltage component of the oscillation signal V_{OSC} are maintained. Accordingly, the AC voltage signal V_1 has same phase, amplitude and level of the DC voltage V_{DC} as the oscillation signal V_{OSC} generated from the oscillator 402.

A sampling pulse generator 406 receives the oscillation signal V_{OSC} output from the oscillator 402 and generates a sampling pulse signal V_R. The sampling pulse signal V_R has a same phase as the AC voltage signal V_1. A synchronous detector 408 receives the AC voltage signal V_1 and the sampling pulse signal V_R output from the current

amplifier 404 and the sampling pulse generator 406, respectively, and portions of the AC voltage signal V_1 having a same phase as the sampling pulse signal V_R are partially detected and output as a detection output signal V_2.

A bridge circuit 428 includes a coil circuit that includes a temperature compensation coil L_1 and a torque detection coil L_2 connected in series to each other, and a resistor circuit that includes a first resistor R_1 and a second resistor R_2 connected in series to each other. The detection output signal V_2 output from the synchronous detector 408 and the DC voltage V_{DC} are applied to both ends of each of the coil circuit and the resistor circuit, respectively. A first detection voltage V_C through which torque on a steering wheel is detected is obtained at a connecting point at which the temperature compensation coil L_1 and the torque detection coil L_2 are connected to each other.

A principle of torque detection on the steering wheel by use of the bridge circuit 428 is as follows. A torsion bar is disposed between a wheel driving shaft and a steering wheel driving shaft, and the torsion bar is twisted by rotation of the steering wheel. The twisting of the torsion bar varies magnetic flux around the torque detection coil L_2, so that a magnitude of an inductance of the torque detection coil L_2 varies with the variation of the magnetic flux. Accordingly, torque on the steering wheel is detected by measuring the variation of the inductance of the torque detection coil L_2.

The temperature compensation coil L_1 is a compensation device that may detect variation of inductance of the torque detection coil L_2 due to twisting of the torsion bar. The inductance of the torque detection coil L_2 of the coil circuit varies with rotation of the steering wheel and variation of temperature, but the inductance of the temperature compensation coil L_1 varies with only the variation of temperature and does not vary with the rotation of the steering wheel. That is, since the variation of the inductance of the temperature compensation coil L_1 is caused by disturbance such as variation of

temperature of surroundings, the variation of inductances caused by the temperature variation of surroundings is eliminated when the inductance of the temperature compensation coil L_1 is cancelled from the inductance of the torque detection coil L_2, so that the variation of the inductance of the torque detection coil L_2 caused by only rotation of the steering wheel may be detected. A second detection voltage V_E having same phase and amplitude as the first detection voltage V_C is obtained when an inductance of the temperature compensation coil L_1 is equal to an inductance of the torque detection coil L_2 at a connecting point between the first and second resistors R_1 and R_2 of the bridge circuit 428. Torque detection of the steering wheel is achieved by comparing the first detection voltage V_C of the coil circuit with the second detection voltage V_E and obtaining a difference therebetween.

The torque detector of the present invention generates a torque detection signal T_S by differentially amplifying peak values of the first detection voltage V_C and the second detection voltage V_E obtained by the bridge circuit 428. In FIG. 4, a first peak detector 410 detects the peak value of the second detection voltage V_E and generates a second peak detection voltage V_{P4}, and a second peak detector 412 detects the peak value of the first detection voltage V_C and generates a first peak detection voltage V_{P3}. A difference between the second and first peak detection voltages V_{P4} and V_{P3} output from the first and second peak detectors 410 and 412, respectively, is amplified by a differential amplifier 414, and converted into a current form by a voltage-to-current converter 416, thus producing the torque detection signal T_S. The torque detection signal T_S may be used to drive a motor that provides an auxiliary driving force to a steering system. In FIG. 4, resistors R_1' and R_2', third and fourth peak detectors 418 and 420, a differential amplifier 422, and a voltage-to-current converter 424 constitutes an auxiliary fail-safe circuit.

FIG. 5 is a graph showing the AC voltage signal V_1 and the sampling pulse signal V_R output from the current amplifier 404 and the sampling pulse generator 406, respectively. It can be appreciated from FIG. 5 that the phases of the AC voltage signal V_1 and the sampling pulse signal V_R coincide with each other. FIG. 6 is a diagram showing the detection output signal V_2 and the sampling pulse signal V_R output from the synchronous detector 408 and the sampling pulse generator 406, respectively. As shown in FIG. 6, the detection output signal V_2, which are formed of only portions of the AC voltage signal V_1 corresponding to more than the level of the DC voltage, is produced by partial detection of by the synchronous detector 408.

FIG. 7 is a graph showing amplitude variation of the first detection voltage V_C according to inductance variation of the temperature compensation coil L_1 and the torque detection coil L_2. As shown in FIG. 7, when the steering wheel does not rotate, the inductance of the temperature compensation coil L_1 is equal to the inductance of the torque detection coil L2, so that a first detection voltage V_{C1} having a reference amplitude is detected. In contrast, when the steering wheel rotates in a Counter-ClockWise (CCW) direction, the inductance of the temperature compensation coil L_1 is larger than the inductance of the torque detection coil L_2 by an operation of the torsion bar, so that a first detection voltage V_{C2} having an amplitude greater than the reference amplitude of the first detection voltage V_{C1} is detected. Additionally, when the steering wheel rotates in a ClockWise (CW) direction, the inductance of the temperature compensation coil L_1 is smaller than the inductance of the torque detection coil L_2 by an operation of the torsion bar, so that a first detection voltage V_{C3} having an amplitude less than the reference amplitude of the first detection voltage V_{C1} is detected. FIG. 8 is a graph showing the second detection voltage V_E obtained in the connecting point between the first and second resistors R_1 and R_2. The torque on the steering wheel may be detected through

a difference between the second and first detection voltages V_E and V_C.

Relation between the rotation direction of the steering wheel and the inductance of the coil circuit including the two coils L_1 and L_2, and the first detection voltage V_C is shown in Table 1.

Table. 1

Rotation direction	Inductance	Voltages
CW	$L_1 < L_2$	$V_C > V_E$
Stationary	$L_1 = L_2$	$V_C = V_E$
CCW	$L_1 > L_2$	$V_C < V_E$

FIG. 9 is a diagram showing the first peak detection voltage V_{P3} output from the second detector 412 according to phase variation of the first detection voltage V_C in the torque detector, according to the present invention. As shown in FIG. 9, the second peak detector 412 according to the present invention detects peak values of the first detection voltage V_C, and outputs the first peak detection voltage V_{P3} of a DC voltage level a corresponding to the detected peak values. Accordingly, the same peak detection voltage V_{P3} is obtained without being influenced by phase variation of the first detection voltage V_C caused by impedance variation of the coil circuit, so that distortion of the torque detection signal T_S may be prevented.

As apparent from the above description, the present invention provides a torque detector, which synchronously detects an oscillation signal, applies the synchronously detected oscillation signal to a coil circuit including a temperature compensation coil and a torque detection coil, and differentially amplifies peak values of a detection voltage obtained in a connecting point between the two coils and a reference voltage, thus preventing distortion of a torque detection signal according to phase variation of the

detection voltage.

Although a few preferred embodiments of the present invention have been shown and described, it would be appreciated by those skilled in the art that changes may be made in these embodiments without departing from the principles and spirit of the invention, the scope of which is defined in the claims and their equivalents.